



THRUSTERS

Reliable Prediction of Steerable Thruster Systems Based on Condition Measurements

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Wärtsilä Ship Power

October 7-8, 2008

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0. Agenda

1. Introduction
2. The thruster system
3. Design aspect of mechanical systems
4. Reliability of steerable thruster based on field analysis
5. Conclusions

1. Introduction

Reliability is the ability of the equipment unit to perform its stated duty without a forced (unscheduled) outage in a given period of time

By William E Forsthoffer (Reliability optimization through component condition monitoring and root cause analysis)

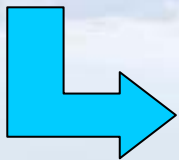
1. Introduction

- Scope
 - Combined use of CMS and reliability engineering for improvement of total life cycle operation
- Why is it important
 - Better understanding of system and component characteristics, based on service measurements
 - Find underlying factors for improvement
 - Provide effective ways to support expected system behavior
 - Serve as a basis for maintenance programs and life cycle costs
- What do we want to achieve
 - Better prediction of maintenance, reliability and availability
 - Better design for improved overall performance and reduced maintenance
 - Improved availability
 - Better understanding of system behavior

2. Thruster System

What can go wrong

- Seal damage: water content in lub. oil
reduces the life time of bearings and gears with 50%
- Inadequate lubrication: due to late filter / oil change
- Overloading of the thruster
- External impacts



- Eventually this leads to early wear of gears and bearings
- Wear particles spread through the unit and affect other “healthy” components



**THE HEALTH OF THE THRUSTER SLOWLY
BUT STEADILY DETERIORATES**

2. Thruster System

Results of malfunctions

- Unplanned maintenance / repairs
- Replacement parts
- Loss of redundancy (Class)
- Docking



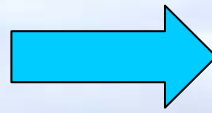
2. Thruster System

Development CMS

Today

Alarms

- pressure
- temperature
- level



Tomorrow

Monitoring

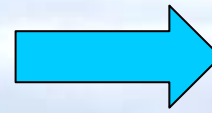
Early detection
of deteriorating
components:

- vibrations
- moisture
- particles



Result -> signals:

- detect early changes
- make trend line



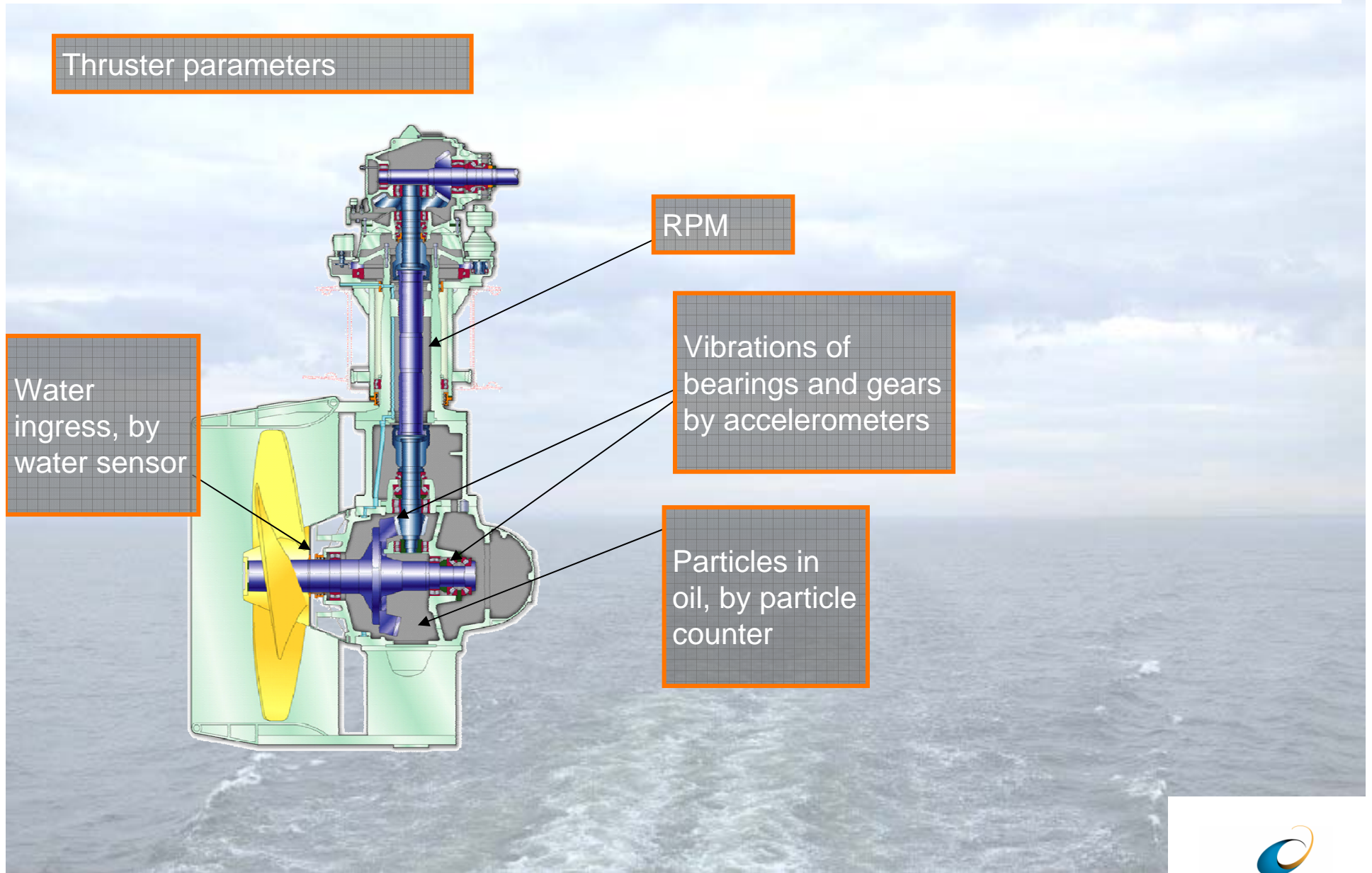
Future

Diagnostics / prognostics

- combine signals, remaining lifetime
- database

2. Thruster System

Monitoring what....



2. Thruster System

Monitoring what....



3. Design aspects of mechanical systems

Failure Mode Effect and Criticality Assessment (FMECA):

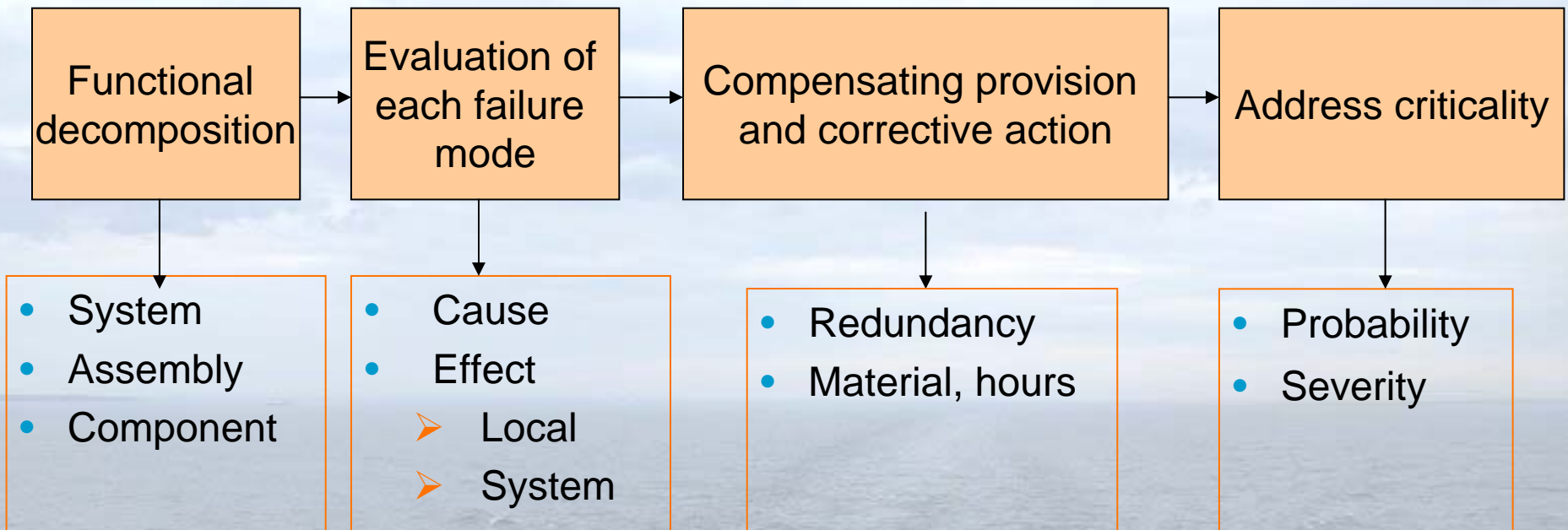
- Clear vision on the various ways equipment may fail -> intrinsic and exogenous failure processes.
- Room for subjective assessment of criticality and the effect of maintenance interventions.

Quantitative decision support:

- Quantified analysis of the various maintenance strategies:
 - Functional failures and repair activities as realisations of chance processes.
 - Characterised by a probability distribution (mean and spread in failure and repair time).

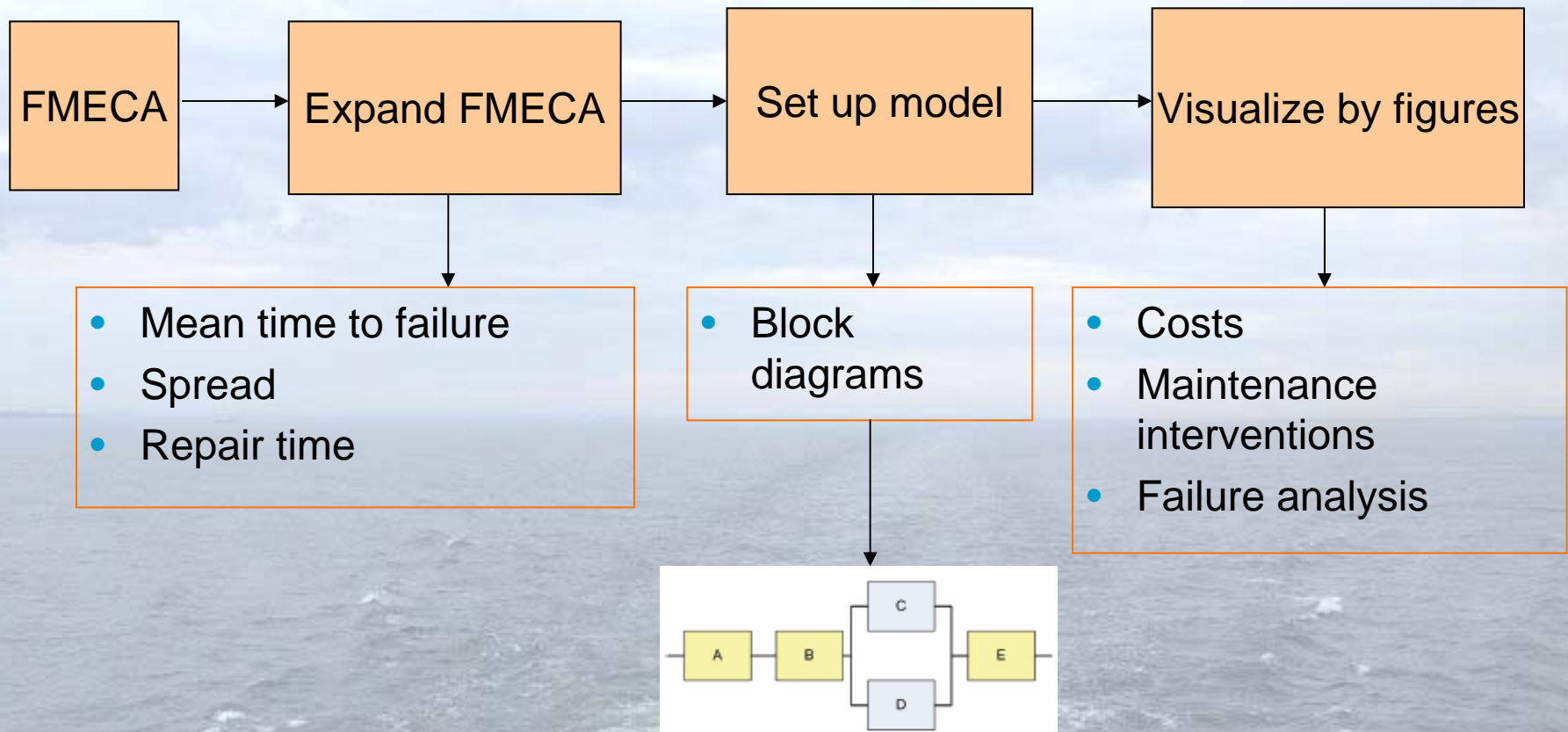
3. Design aspects of mechanical systems

Set-up FMECA



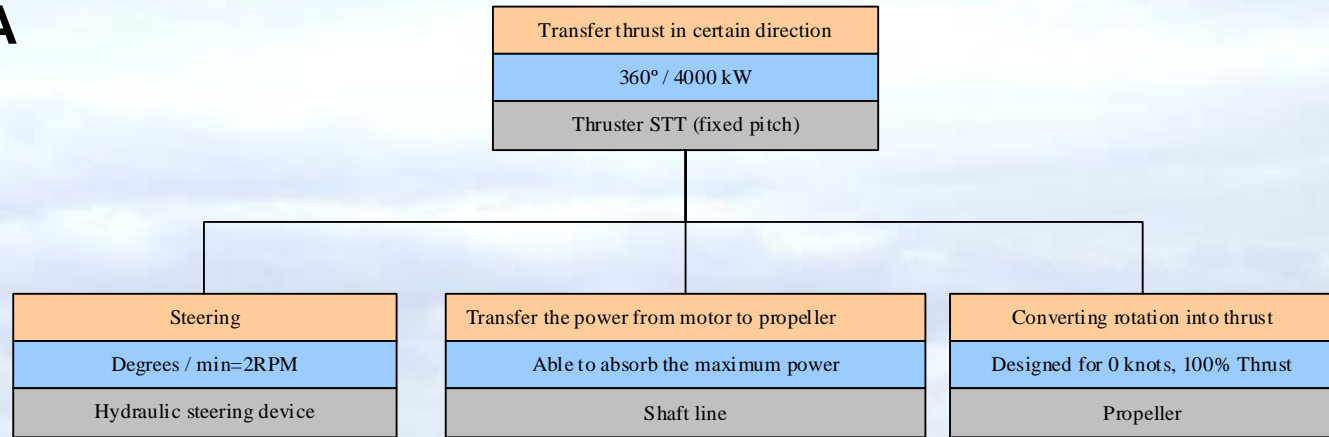
3. Design aspects of mechanical systems

Set-up Quantitative decision approach



3. Design aspects of mechanical systems

Result FMECA



| Level | Module | Failure Mode | Local Effect | System effect | Probability | Severity | | | | Score | Failure Cause |
|-------|-----------|--------------|----------------|-------------------------------|-------------|----------|------|---------|------|-------|-------------------------|
| | | | | | | Saf. | Env. | Op.cap. | Cost | | |
| B3 | Propeller | Broken blade | No more thrust | System has lost main function | 1 | 2 | 2 | 16 | 16 | 16 | Extreme external events |

| System/Assembly | Score |
|------------------|-------|
| Bearings | 32 |
| Gearset PGB | 16 |
| Propeller | 16 |
| Shaft | 16 |
| Steering gearbox | 16 |

Score = Prob. x Sev.(highest)

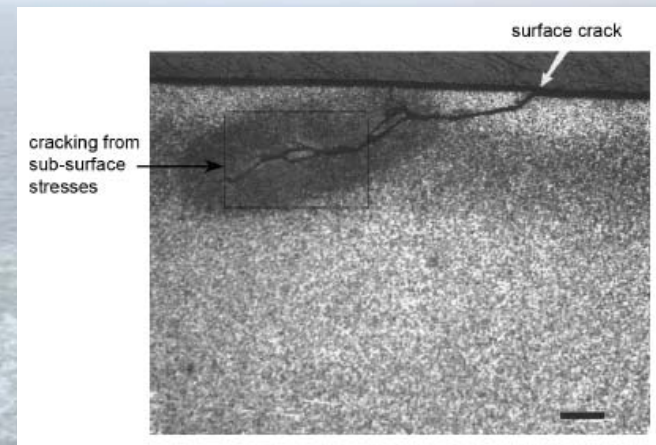
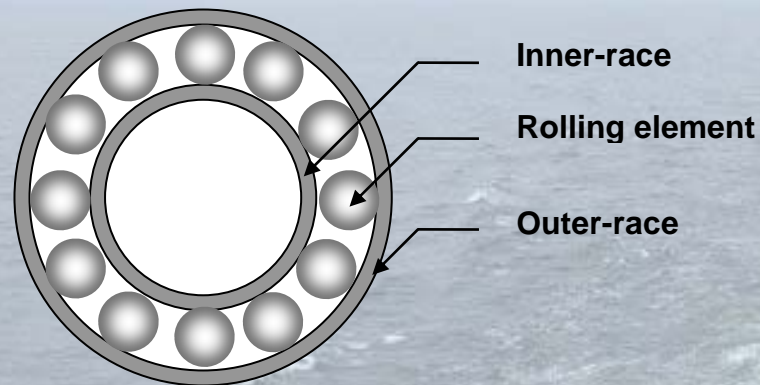
Probability: 1,2,3,..5

Severity: 1,2,4,..16

3. Design aspects of mechanical systems

Information Failure Modes Roller bearings

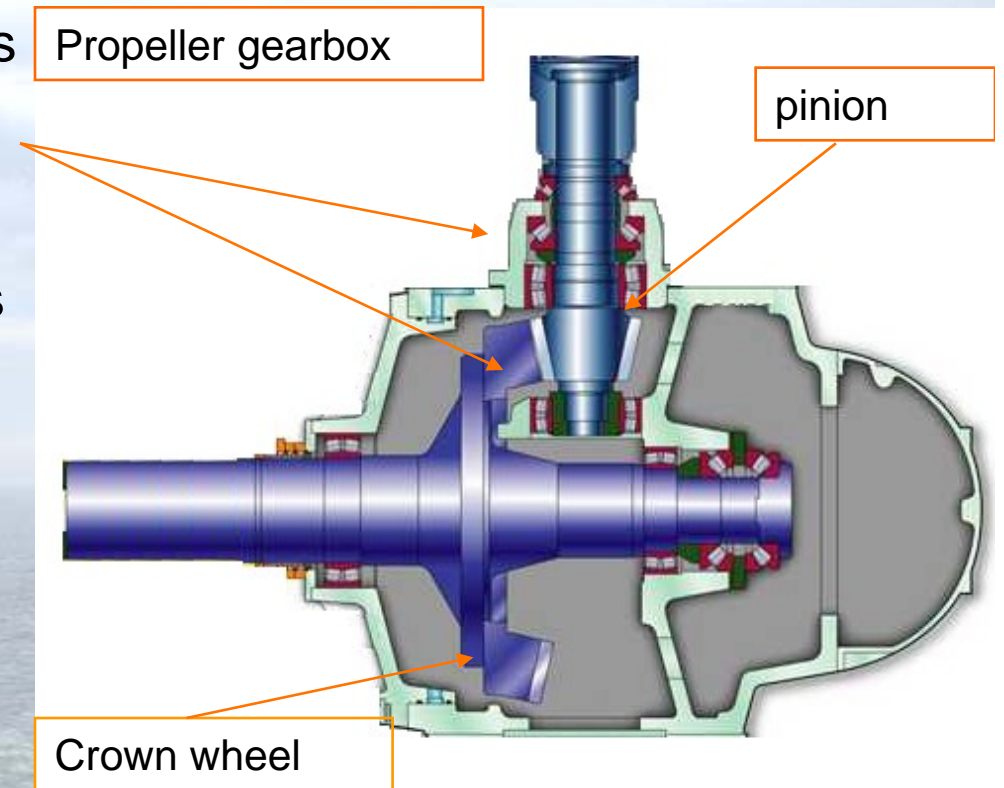
- Failure mode: Fatigue damage
- Failure mechanism: Spalling, brinelling
- Failure cause: Heavy prolonged load, excess speed, shock load, excessive vibration



3. Design aspects of mechanical systems

Optimal design criteria:

- Pinion supported by roller bearings at both sides
- Separate axial and radial bearings
- Precise and stable tooth contact pattern under variable loading (thrust)
- Teeth are finish-machined after hardening



3. Design aspects of mechanical systems

Selection and parameters gears and bearings

Min. 25.000 h lifetime: full continuous load

- Separate bearings for axial and radial load
- Bearing load depends on: torque and thrust
- Double sided support by anti-friction bearings near gearwheels
 - less deformation
 - higher lifetime
- Effect of load profile
- Oil contamination / water ingress / temperature



Infinite lifetime



4. Reliability based on field analysis

Results Quantitative Approach:

- Failure analysis
- Reliability and availability prediction
- Maintenance prediction
 - Preventive
 - Corrective
 - Condition based

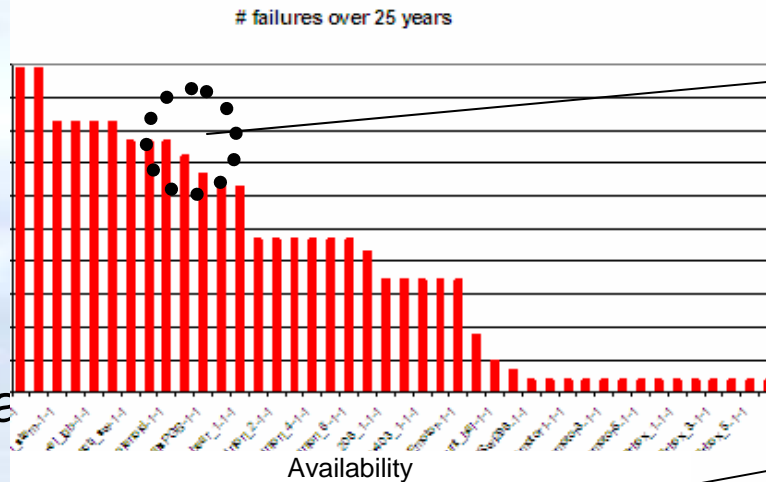
Gears and bearings

4. Reliability based on field analysis

Results Quantitative Approach:

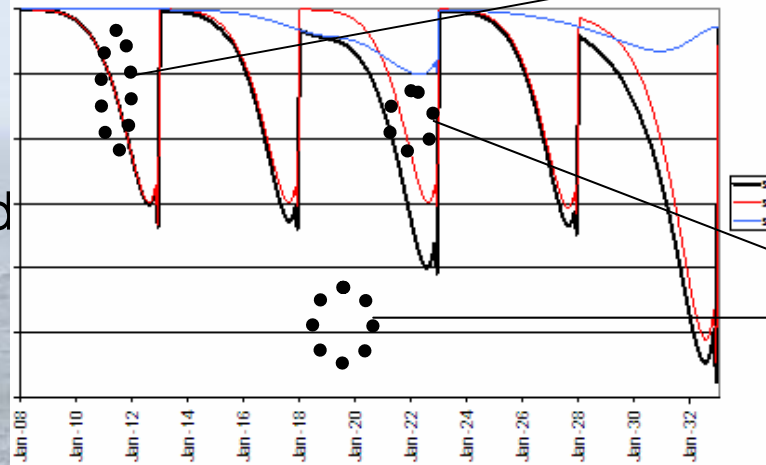
- Failure analysis
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Gears and bearings

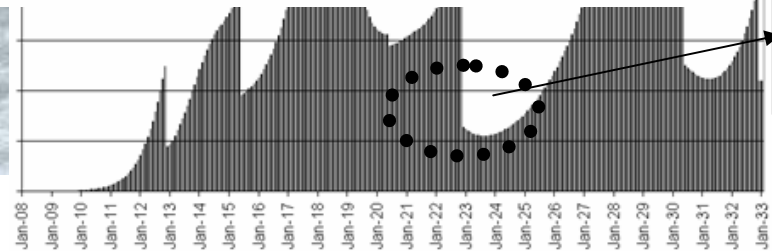


Seals/bearings:
Fail a few times
in 25 years

Shaft line:
High MTTR/
low MTTF of
Seals/bearings



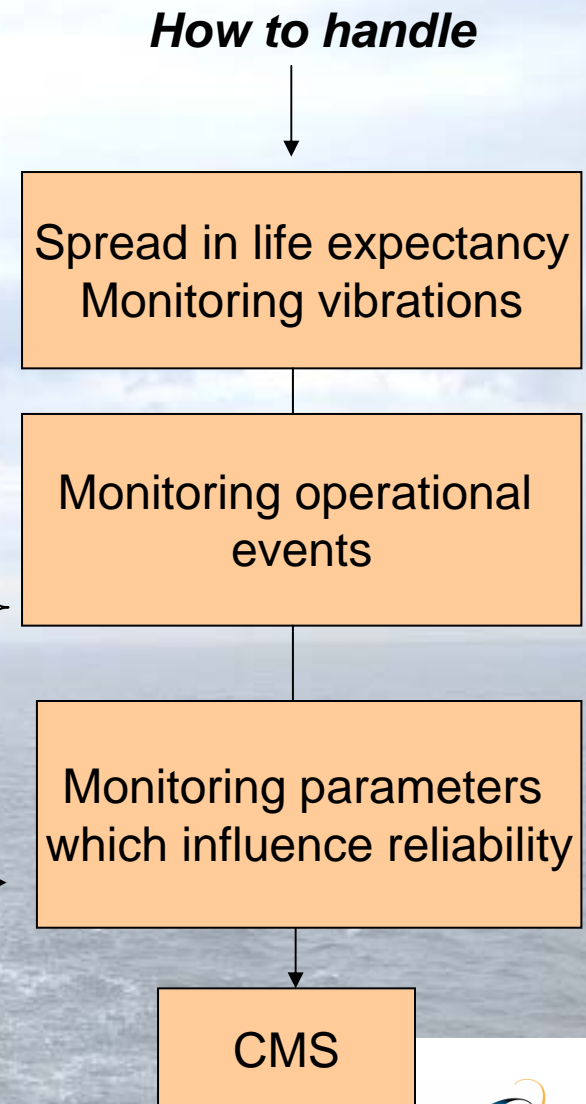
Maintenance:
Intermediate survey /
Health check



4. Reliability based on field analysis

Field information related to failures:

- Slowly progressing failures:
 - Wear-out
 - Fatigue
- Event determined failures:
 - Operator using machinery outside operating envelope
 - Maintenance interactions
 - External reason
- Stochastic failures (suddenly happening):
 - Reliability
 - Human factors in production (manufacturing failure)



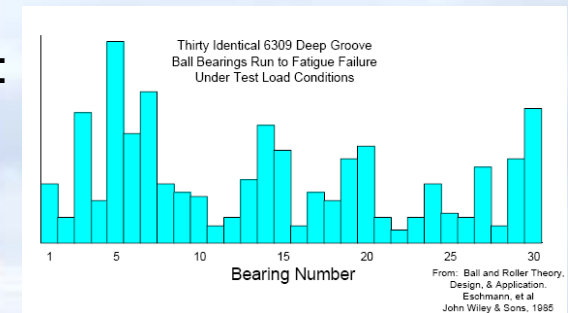
4. Reliability based on field analysis

Reliability combined with condition monitoring

Lifetime expectation:

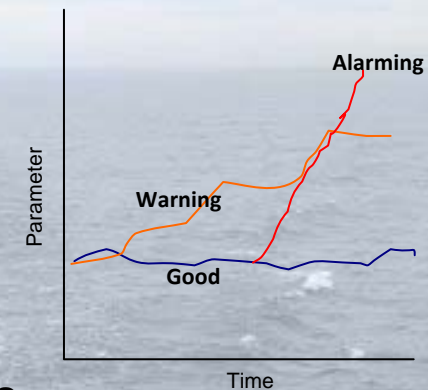
For lifetime expectation a statistical approach is needed:

- Wear-out of bearings is random-> life can only be made in terms of *expected reliability*.
- Use Weibull distribution as an estimate for bearing life



Solution:

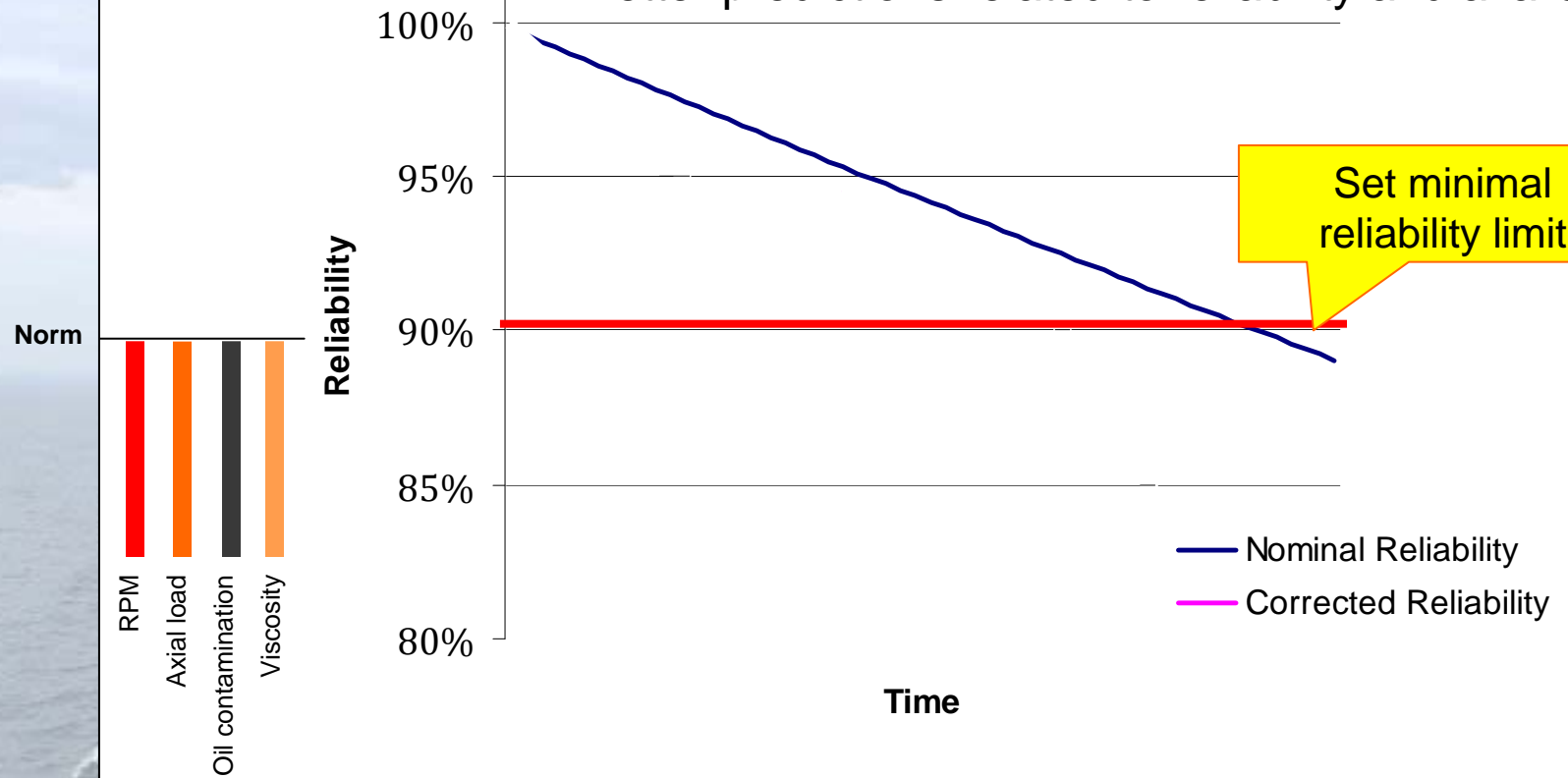
- Measurement of performance and health of system
- Real-time trending and monitoring of parameters which influence reliability



4. Reliability based on field analysis

Result of combination

- Correlation of information as input to perform CBM
 - Evaluate qualitative and quantitative approach
 - Better understanding of system behavior
 - Better predictions related to reliability and availability



From Condition Monitoring to Condition Based Maintenance:

- Give a *condition* of components or system
- Minimize the possibility of the *consequence of damage*
- Possibility of *adjusting maintenance intervals*, depending on the results of CMS
- Better understanding of *component / system behavior*, this can be used for better *predictions for reliability and availability*
- Eventually this approach allows to perform *condition based maintenance*

6. End

Questions?